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METHOD AND MEANS FOR CONTROLLING TEMPERATURES
ADJACENT LIVING BODIES

2,938,356

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2 Sheets-Sheet 1

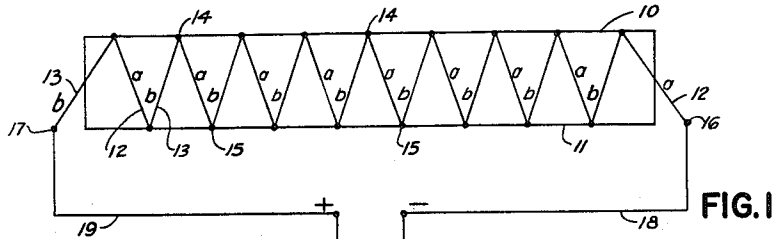


FIG. 1

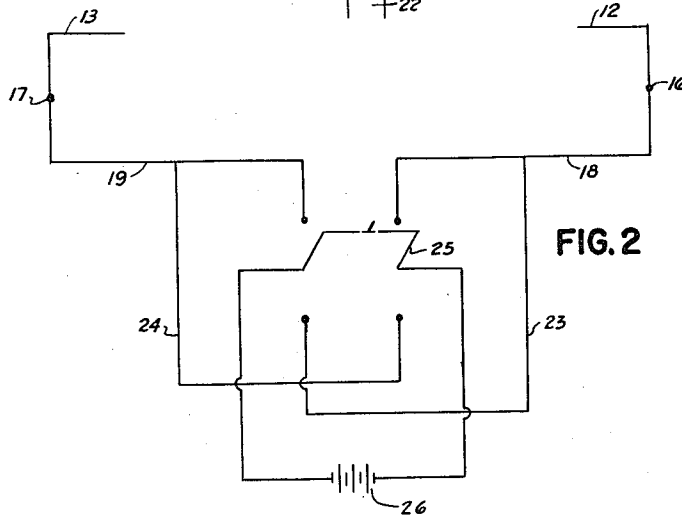


FIG. 2

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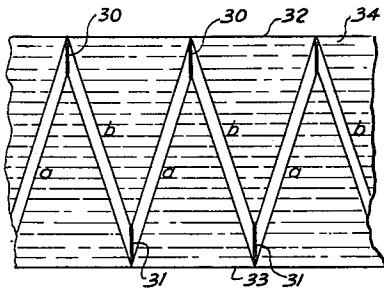


FIG. 3

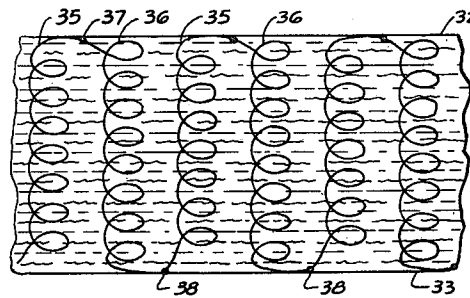


FIG. 4

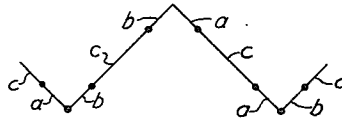


FIG. 5

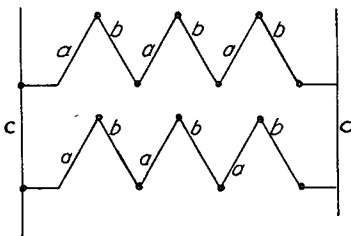


FIG. 6

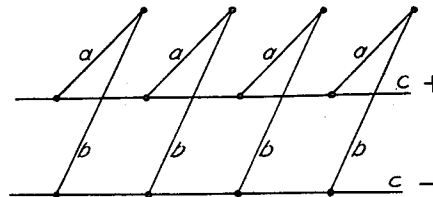


FIG. 7

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METHOD AND MEANS FOR CONTROLLING TEMPERATURES ADJACENT LIVING BODIES

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15 Claims. (Cl. 62—3)

This invention relates to devices and equipment associated with the control of animal body temperature and particularly to insuring maximum comfort to humans and other animals under ambient conditions of excessive heat or cold.

Electrically-heated blankets, sheets, flying suits and similar apparel are known and widely used and accepted. However, to my knowledge, there does not exist bedding or apparel capable of maintaining a cooling surface or area about a human or animal body as the blankets and flying suits maintain a heating surface or area. Bedding, apparel or other equipment which can keep a human being cool while exposed to uncomfortably-warm ambient conditions offers a field of utility which is equally as large as that for the present-day electrically-heated blankets, etc. Thus, such bedding in the form of sheets, blankets and mattresses may be used to keep an individual cool in the summertime in normally temperate climates, or all year around in tropical climates. Likewise, a flying suit constructed according to this invention may be worn by a jet pilot to reduce or eliminate the discomfort now encountered because of the heat of friction generated in the jet plane's flight and transmitted into the pilot's cabin.

Although the principle of this invention is particularly suited to equipment and apparel to be used for cooling purposes in warm or even hot atmospheres, it is equally suited to equipment for warming the human body in cold atmospheres.

It is therefore an object of this invention to furnish a mechanism by which bedding, apparel and other equipment may provide either a heating or a cooling effect at the option of the user. It is an additional object to furnish such bedding, apparel and other equipment so that it may be used to regulate the temperature of an area or surface surrounding the human body. It is a further object to furnish bedding such as sheets, blankets and mattresses which may be cooled or heated. It is still another object of this invention to furnish apparel which may either cool or heat the individual wearing it, as desired by the wearer from time to time. These and other objects will become apparent in the following detailed description of this invention.

The equipment and apparel of this invention are so constructed that they contain within them a number of junctions between segments of two dissimilar conductors, such junctions being so arranged that those having the dissimilar conductors in the same relationship to each other are contiguous to one surface of the equipment or apparel and those of all of the opposite relationship are contiguous to the opposite surface thereof.

Briefly the equipment or apparel of this invention may be described as a flexible supporting material of low thermal conductivity which has embedded in it two types of segments each type of which is at least semi-conductive. Each of the segments of one type (called the first type) is connected in series-circuit relationship between two segments of the other (second) type, while each of the

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second type is connected similarly in series-circuit relationship between two segments of the first type. Means are provided for passing a direct current through this series of alternating segments and the junctions are so arranged that the direct current may pass from all of the first type segments to all of the second type segments near one surface of the supporting material and from all of the second type segments to all of the first type segments near the other surface of the supporting material.

It is known that when current is passed through a junction of two such dissimilar conductors, heat will be absorbed or given off at the junction depending upon the direction of the current. Thus cooling or heating will be achieved by the junctions, depending upon the relative positions of the two dissimilar conductors. This is known as the Peltier effect, and it has been suggested as a means for producing conventional refrigeration. However, in the case of conventional refrigeration, so-called Peltier cooling has not appeared economical because of low efficiencies attained where relatively large temperature differences are involved. I find that such drawbacks are not present in applying Peltier cooling to bedding, apparel and other similar equipment since the temperature differentials required are generally small, the refrigeration load is small and the refrigeration can be applied directly to the surface or area where it is desired, thus making relatively low efficiencies still economical.

The process and equipment of this invention will be explained in detail and with reference to the accompanying drawings in which

Fig. 1 is an enlarged, diagrammatic cross-sectional view of a fabric or blanket containing the junctions and showing the wiring diagram for a typical circuit;

Fig. 2 illustrates an alternate wiring diagram, using a battery;

Fig. 3 illustrates how the principle of this invention may be applied to a foam rubber type mattress;

Fig. 4 illustrates how the springs of a mattress may be wired to be used as the dissimilar conductors required to form the Peltier junctions;

Fig. 5 shows how multiple-metal segments may be used; and

Figs. 6 and 7 illustrate two ways in which the dissimilar conductors may be wired in parallel relationship.

The Peltier effect is the thermodynamic converse of the thermoelectric (Seebeck) effect. When a current is made to pass through a junction of two dissimilar conductors, heat is absorbed or generated at the junction, depending on the direction of the current. If the current is made to pass in the same direction as the thermoelectric current would flow when the junction is heated, heat is absorbed. If the current is made to pass in the opposite direction, heat is generated. In addition to the Peltier effect there is also present the Joule effect which is an irreversible heat effect due to a current flowing through a resistance and which is therefore independent of the direction of the current. This Joule effect is an additive one which contributes to the efficiency of a system used for heating as discussed below.

In Fig. 1 there is illustrated a cross-section of a supporting material made up of a type of fabric such as would be suitable for a blanket or the material for a flying suit. In such a material there is a top surface 10 and bottom surface 11 which contain in the space between them short segments of a conductor 12 and b conductor 13 contacted at junctions 14 and 15.

Since the direction of the current flowing through the circuit will determine, for a given set of dissimilar conductors, which junctions will absorb heat and which will give off heat, it is necessary to assume a current direction

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in Fig. 1 in discussing it. Assume, therefore, that the current is flowing in a clockwise direction and is such that all $a-b$ junctions absorb heat while all $b-a$ junctions evolve heat. It will be seen then that all junctions of conductor 12-conductor 13 i.e., $a-b$ junctions, such as junction 15 must be located or be contiguous to (touch or come close to) surface 11 while all of the junctions of conductor 13-conductor 12, $b-a$ junctions, as indicated by 14 in Fig. 1 must be contiguous to surface 10. In this example then, surface 11 should be in direct contact with the body if a cooling effect is sought and surface 10 should be in direct contact if a heating effect is sought.

One possible wiring circuit is also illustrated in Fig. 1. From the terminal wires of conductors a and b lead wires 18 and 19 are joined at junctions 16 and 17, respectively. Such lead wires 18 and 19 are conveniently of a metal such as copper which is a good electrical conductor. When the source of electrical energy 22 is alternating current then it must be conducted through rectifier 20, by way of transformer 21, so that the current entering the system is direct current. Alternating current cannot be used for the obvious reason that rapidly alternating the direction of current flow would mean alternately cooling and heating each surface thus defeating the purpose of the invention.

To convert a cooling blanket, for example, to a heating blanket, a scheme such as illustrated in Fig. 2 may be used. In this example, a double pole-double throw switch, along with its necessary connections, is used to reverse the direction of current flow into lead wires 18 and 19 which are as in Fig. 1 joined to the terminals of the dissimilar conductors 12 and 13. Of course, the simple expedient of turning the blanket over is equally effective. Although this latter method is convenient for blankets, sheets and the like which are light in weight and easily turned over, the reversal of current is preferable for heavy items such as mattresses and for equipment such as flying suits which are not easily reversed.

Since the current requirements are relatively small (of the order of 2 amperes) portable batteries may be used as a source of electrical supply as well as A.C. or D.C. current from a line. Thus, Fig. 1 shows an A.C. line source whereas Fig. 2 shows a series of batteries 26. Of course, a double pole-double throw switch such as shown in Fig. 2 would be equally adaptable to the circuit of Fig. 1 for reversing the direction of current flow. Any other suitable means for reversing the current flow would also, of course, be satisfactory.

In Figs. 3 and 4, there are illustrated two possible ways in which mattresses may be constructed in accordance with this invention. Thus, in Fig. 3 conductors a and b may be incorporated into foam rubber 34 to form junctions 30 and 31 which touch or lie adjacent or are contiguous to the top 32 and bottom 33 of the mattress, respectively. In Fig. 4 the alternate springs 35 and 36 are constructed of conductors a and b , respectively, and are joined to form junctions 37 and 38 which touch or are adjacent top 32 and bottom 33 of the mattress. Wiring circuits similar to that shown in Figs. 1 or 2 can be used for the types of mattresses shown in Figs. 3 and 4.

The difference between ambient temperatures and that temperature which will be comfortable to the human body is usually relatively small compared to the difference between ambient temperature and the temperature required for household refrigeration, for example. The actual temperature at which the bedding or apparel should be maintained can generally be defined as that temperature which will most easily permit maintenance of normal body temperature. Under usual circumstances, this will mean removing only about that quantity of heat generated by the body if cooling is to be achieved, or supplying that quantity of heat which escapes if heating is to be done.

It may therefore be seen that the use of Peltier cooling for the bedding, apparel and like equipment of this inven-

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tion is practical because of the relatively small temperature differentials involved which means that only a few B.t.u.'s (of the order 250 B.t.u./hour) must be handled and relatively few kilowatts must be supplied. Furthermore, in the case of this invention, refrigeration or heating is applied within a very limited area just where it is needed so that losses are minimized, making it economical to use Peltier cooling in spite of relatively low efficiencies.

When equipment of this invention is used to heat the body the efficiency is materially enhanced by the so-called Joule heating effect. This heating is brought about by the resistance to current flow in the segments, the junctions of which furnish heating or cooling, and it is available as additional heat. In addition to the fact that the Joule heat is available, a heating blanket of this invention has another inherent thermodynamic advantage. When heating is to be achieved, the side of the blanket which contains the junctions absorbing heat is turned to the cold ambient air. Thus, these junctions in cooling are in effect pumping heat out of the room and adding it to the blanket. These factors of added Joule heat and absorption of heat from the surrounding atmosphere contribute materially to the overall efficiency of a blanket, apparel or other equipment made according to this invention.

A number of combinations of dissimilar conductors are available which exhibit the Peltier effect. Such combinations include two different metals, a semi-conductor with a metal, a p-type or n-type semi-conductor with a metal, and a p-type semi-conductor with an n-type semi-conductor. Although all such combinations are capable of exhibiting the Peltier effect, the choice of conductors is preferably made from those having large thermoelectric power, low thermal conductivity and high electrical conductivity. Other factors, such as malleability, ductility, ease of soldering and welding will also influence the choice of the conductors.

Since metals such as copper, silver, etc., and their common alloys obey the Wiedemann-Franz law (i.e., the ratio of electrical to thermal conductivity is approximately constant) it means that they show both high thermal and high electrical conductivity and relatively low thermoelectric power. Thus, presently-known metals are not particularly well suited to application for this invention. However, a number of the so-called semi-conductors, although they exhibit electrical to thermal conductivity ratios less than those of the metals, have much greater thermoelectric power. Thermoelectric power is an expression used to describe the basic electronic activity within the semi-conductor as a function of temperature. Thus, its relationship to Peltier performance becomes immediately apparent. Semi-conductors may be used in conjunction with metals. For example, using semi-conductors such as Bi_2Te_3 , PbTe , HgTe , PbSb , InSb , etc., with a metal such as bismuth or germanium gives materially better performances than using two metals. The Peltier effect may be further enhanced beyond the performance achieved by such conductor combinations by using an n-type or p-type semi-conductor as one or both of the materials forming the junction. The choice between the n-type and p-type semi-conductor will depend upon the metal or semi-conductor used for the other material. (The theory of semi-conductors and their n- and p-types is discussed fully in "Electrons and Holes in Semi-Conductors" by William Shockley (Van Nostrand, N.Y., 1950).)

In choosing the semi-conductors most suitable for application to this invention, it should be noted that the heat conductivity of the semi-conductor decreases with increasing atomic weight, whereas the carrier mobility (a primary factor in electrical conductivity) has a tendency to increase. Thus, from an efficiency point of view, the semi-conductors are preferably chosen from those having the highest mean atomic weights.

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Among many combinations of unlike materials which may be used to form the junctions for the process of this invention may be listed

Bi_2Te_3 —Bi
 Bi_2Te_3 (n-type)— Bi_2Te_3 (p-type)
 Ge(n-type)—Ge.

The conductor segments may also consist of a multiple of sections such as illustrated in Fig. 5. Thus the segments may be made up of sections of a semi-conductor, or other conductor which displays the Peltier effect, at their terminal ends where they are to form the Peltier junction and intermediate sections of metal conductors having suitable electrical and thermal conducting properties. For example, in Fig. 5 sections *a* and *b* may be semi-conductors while section *c* may be copper or the like. The type of mattress illustrated in Fig. 4 is an example of an application of this multiple-section type of segment. Thus the main portion of the springs 35 and 36 (Fig. 4) may be of any suitable metal conductor joined to terminal sections which form the junctions 37 and 38.

Likewise, Figs. 6 and 7 illustrate how a third type conductor may be employed to obtain a parallel type of wiring which may achieve greater current flow. Thus in Fig. 6 a group of a plurality of *a*—*b* and *b*—*a* junctions are joined in parallel with similar groups by means of conducting material *c*. As in the previous illustrations, all of the *a*—*b* junctions are located on one side and all of the *b*—*a* junctions on the other side. In such a wiring arrangement, as shown in Fig. 6, the wire connecting all of the terminal *a* segments may be of *b* conductor and that wire connecting all of the terminal *b* segments may be of *a* conductor. However, this would be practical only if the heating or cooling in these terminal junctions was relatively small compared to the effects desired from the *a*—*b* and *b*—*a* junctions.

Fig. 7 illustrates another type of parallel wiring arrangement so that when the *a*—*b* junctions absorb heat the *a*—*c* and *b*—*c* junctions generate heat, and when the *a*—*b* junctions generate heat, the *a*—*c* and *b*—*c* junctions absorb heat. Such an arrangement may be conveniently used when the function of the *a*—*c* and *b*—*c* junctions is to be preferred over the function of the *a*—*b* junctions.

The supporting material which may be used to form the outside layers of the bedding or apparel of this invention may be of any suitable material including the natural and synthetic fibers. It should of course preferably be an electrically non-conducting material, or one of low electrical conductivity, and possess a degree of flexibility commensurate with the use for which it is intended. That is, if the final article is to be an aviator's suit or a blanket, the supporting material will be much more flexible than if a mattress is to be constructed in accordance with this invention.

In the case of a blanket or sheet used primarily for cooling effects, it may be preferable to use materials which are somewhat porous in nature so that the moisture given off by the body may be permitted to dissipate into the atmosphere through the sheet or blanket. Likewise a type of porous material may be desirable for flying suits or clothing where a cooling effect is to be achieved. Supporting materials such as an air-quilt, which are gas filled, may also be used to furnish a cooling or heating surface according to this invention.

The thickness of the supporting material will be determined by considering such factors as ultimate use of the article to be made, the degree of thermal insulation attained by the supporting material, the amount of Joule heating generated by the segments, the length of the segments used, and the amount of heating or cooling sought. Final thickness determination may require a balancing of these factors.

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In the construction of the bedding and apparel of this invention it may be desirable to thermally insulate the sections of the dissimilar conductors forming the junctions to obtain the maximum efficiency of cooling or heating from the junctions. In the case of such applications as a mattress or relatively thick blanket or wearing apparel some form of fibrous or even rubber-like material may be used with the wires embedded in the supporting material or thermal insulation.

It will be seen that by the process of this invention, it is possible to provide such items as bedding, wearing apparel and like equipment which are capable of materially adding to the comfort of a human being or other animal by providing a surface or area close about the living being which can afford a cooling or heating effect, whichever is desired. Moreover, one single item of such a nature can furnish cooling or heating, it being necessary only to operate a switch or the like which reverses the current flow through the equipment. Since the amount of refrigeration or of heating required is small (relative to conventional systems) and since the refrigeration or heating is accomplished precisely where it is required (thereby minimizing heat losses) the use of Peltier cooling is economically feasible for application in the equipment of this invention.

I claim:

1. An article of manufacture suitable for controlling the temperature adjacent a living body and adapted to be placed in contact therewith, comprising a supporting flexible material of low thermal conductivity and a series of at least semi-conductive segments of a first type and of a second type embedded in said material, each of said segments of said first type being connected in series-circuit relationship between two of said segments of said second type, each of said segments of said second type being connected in series-circuit relationship between two of said segments of said first type, said series of segments being adapted for passage of direct current therethrough, and the respective junctions between said segments of said first type and said segments of said second type being so arranged that said current may pass from each segment of said first type to a segment of said second type near one surface of said material and from each segment of said second type to a segment of said first type near the other surface of said material, the junctions adjacent said one surface being heat-absorbing and those adjacent said other surface being heat-generating when a direct electric current is passed through said series of segments.

2. An article in accordance with claim 1 wherein said supporting material is a blanket.

3. An article in accordance with claim 1 wherein said supporting material is a mattress.

4. An article in accordance with claim 1 wherein said supporting material is a fabric capable of being formed into wearing apparel.

5. An article in accordance with claim 1 wherein said supporting material is porous.

6. An article in accordance with claim 1 wherein said supporting material is air-filled.

7. In a device suitable for controlling the temperature adjacent a living body and adapted to be placed in contact therewith, flexible supporting means, alternate segments respectively of first and second types and of finite electrical conductivity joined in series and embedded in said supporting means, and means for furnishing direct current to the terminal ends of said series of segments, said segments being arranged so that each segment is of a type dissimilar to both segments adjacent thereto in the series and so that alternate junctions between said segments are contiguous to one surface of said supporting means while the remaining junctions between said segments are contiguous to the other surface of said supporting means, said junctions exhibiting the Peltier

effect when a direct current of electricity is passed there-through.

8. A device in accordance with claim 7 wherein is included means for reversing the flow of said direct current.

9. A device in accordance with claim 7 wherein said junctions comprise semi-conductor and a metal.

10. A device in accordance with claim 7 wherein said junctions comprise p-type and n-type semi-conductors.

11. A device in accordance with claim 7 wherein said junctions comprise bismuth and bismuth telluride.

12. A device in accordance with claim 7 wherein said segments comprise multiple sections.

13. An article of manufacture suitable for controlling the temperature adjacent a living body and adapted to be placed in contact therewith, comprising a supporting flexible material of low thermal conductivity having embedded therein a plurality of junctions of conductive segments being of at least two different types, said conductive segments being materials such that the junction of one combination of said segments will absorb heat and the junction of another combination of said segments will generate heat when a direct current of electricity is passed through all of said junctions, means for passing said current of electricity through all of said junctions, said junctions being so arranged that all of those which absorb heat are contiguous to one surface of said supporting flexible material and all of those which generate heat are contiguous to the other surface of said supporting flexible material.

14. In an article of wearing apparel, alternate segments respectively of first and second types and of finite electrical conductivity joined in series and embedded in a flexible supporting means, and means for furnishing direct current to the terminal ends of said series of segments, said segments being arranged so that each segment is of a type dissimilar to both segments adjacent thereto in the series and so that alternate junctions be-

tween said segments are contiguous to one surface of said supporting means while the remaining junctions between said segments are contiguous to the other surface of said supporting means, said junctions exhibiting the Peltier effect when a direct current of electricity is passed therethrough, said apparel being of low thermal conductivity and electrically insulated, the surface of said apparel which is arranged to be adjacent to the body of the wearer being the aforesaid surface contiguous to which are positioned those of said junctions which absorb heat when said current is passed.

15. An article of wearing apparel comprising a supporting flexible material of low thermal conductivity having embedded therein a plurality of junctions of conductive segments being of at least two different types, said conductive segments being materials such that the junction of one combination of said segments will absorb heat and the junction of another combination of said segments will generate heat when a direct current of electricity is passed through all of said junctions, means for passing said current of electricity through all of said junctions, said junctions being so arranged that all of those which absorb heat are contiguous to one surface of said supporting flexible material and all of those which generate heat are contiguous to the other surface of said supporting flexible material, said one surface being arranged to be adjacent the body of the wearer.

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